13.

The Winter Movements of the Landlocked Alewife, *Pomolobus pseudoharengus* (Wilson).

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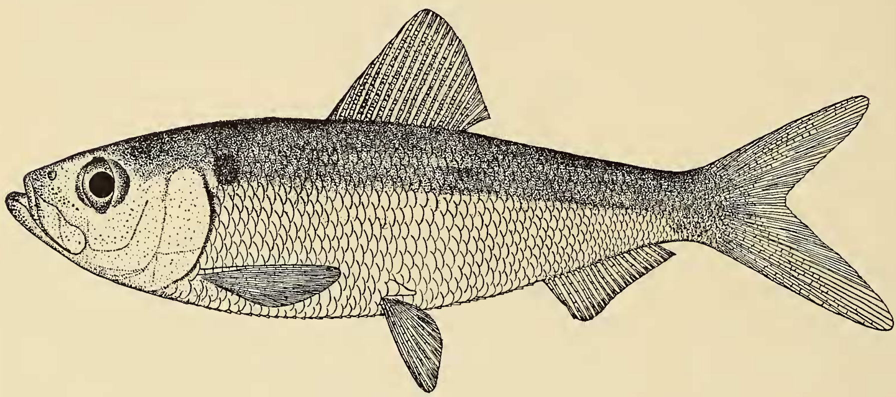
(Text-figures 1-6).

Complaints by householders in New York City of small fishes emerging from their faucets, led Mr. Herman Forster, Deputy Commissioner of the Department of Water Supply, Gas and Electricity, to inquire at the New York Aquarium concerning the possibility of control of these free but unwelcome fishes, see Forster (1935). In order better to understand the problem, a study was undertaken of the conditions reported by him. The fishes were found to be typical landlocked specimens of *Pomolobus pseudoharengus* (Wilson), Text-fig. 1. The data subsequently accumulated uncovered certain features of the behavior of these fishes not hitherto understood and are presented herewith. This study was possible because of certain peculiar features of the environment, due to its being part of the municipal water supply system, added to the cooperation of the Department.

Shortly after the work was undertaken a paper on this same species, Odell (1934), reached our hands, which covered a considerable portion of the ground we had originally planned to include. In view of this and the fact that the New York State Conservation Department Biological Survey was to cover our territory in its 1936 work, we abandoned all but such parts of the original plan that seemed to be complementary to the work of Odell. There is otherwise a marked dearth of papers on this species and since Odell has indicated their contents it is not necessary to refer to them here, especially since their bearing on present problems is slight. Specifically, Odell had no data on the whereabouts of his fish during the winter months and wrote: "In summer it is wide-ranging in habit, having been taken at all depths down to 160 feet. The winter distribution is unknown." Fortunately it is exactly this latter time which is covered best by our data.

It is during this period that *Pomolobus* appears in the drinking water. During certain years great quantities may be taken from the protective screens which cover the outlet of Kensico Reservoir—the lake which forms the habitat of these fishes. The outlets here referred to drain at a depth of from 30 to 60 feet from the surface. No regular records of the fish on the screens had been kept, which were suited to our studies, but it was a relatively simple matter to have the file of complaints in the Water Department office examined for a period of years. For this information and for permission to use it, we are indebted to Mr. Forster. The data covering eleven years are given by months in Table I. Actually these figures represent all complaints of fish in the water supply, but other species, such as *Perca flavescens* and *Anguilla rostrata,* are so rare as to be negligible. The mean for the eleven-year period shows a very definite peak in October, see Text-fig. 2. Observations made on the screens in 1936 and the fragmentary data of other years at that place show the peak of fish on the screens to occur in February or March. This suggests that the small fish drop down first, or at least scatter out sooner, for they do not appear on the screens until the larger fish form a mat for them to rest against. Since *Pomolobus* is in more or less evidence at the upper end of this lake from about May to September and is not to be found near the outlet until the end of that period, it would clearly seem to follow that there is an autumn movement downstream of both large and small fishes.



Text-figure 1.

The landlocked Kensico Reservoir alewife, locally called sawbelly, *Pomolobus pseudoharengus* (Wilson). A typical example of the year's hatch, 51 mm. standard length, Aug. 23, 1935. Fishes this size and smaller sometimes are found in the municipal water distribution system. (Drawing by Ralph Graeter).

If the number of complaints are plotted by years, as in Text-fig. 3, it becomes evident that there is a wide divergence from year to year in their quantity. Varying economic or political events may be expressing themselves here to some extent—a difficulty not inherent in the treatment of Text-fig. 2, which uses the mean value for a number of years. However this may be, it cannot invalidate the effect of the fishes themselves, the data of which also agree with the memory of workers in the Water Department. In other words there were many *Pomolobus* on the screens in 1926 and greater numbers than ever before were noted on them in 1934 and 1935. The period between these two peaks of abundance as thus measured comes to eight years.

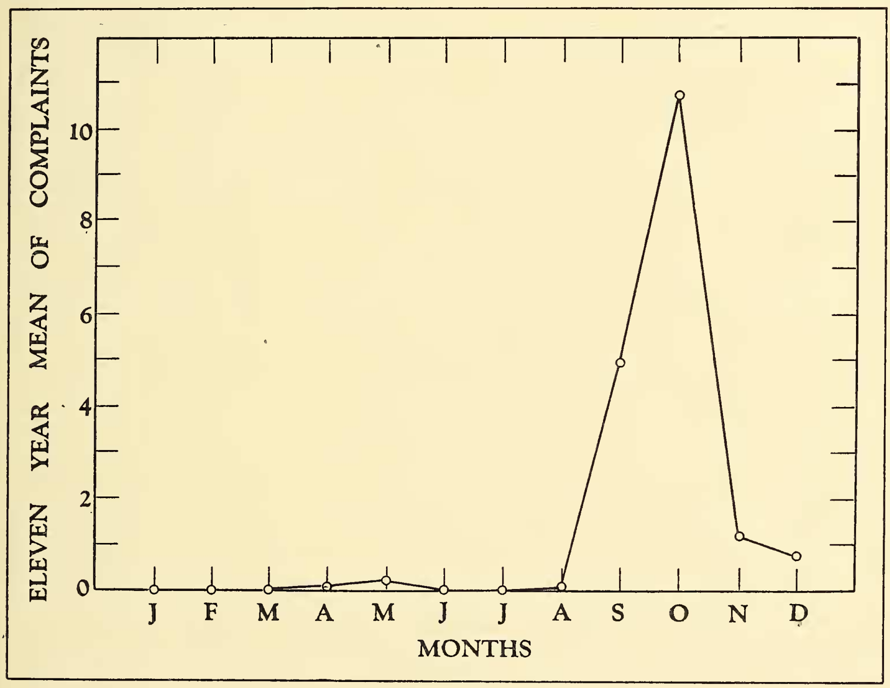
It was impossible to obtain non-selected samples from the screens as to number and size. An unknown number of small fish slipped through the meshes, so that it was not possible even to guess at the quantities or the size composition of the *Pomolobus* that passed the ⅝-inch mesh of the screens. Text-fig. 4 gives some idea of the screens and the fishes removed from them. The screens were removed and cleaned irregularly, according to the quantity of fish collected on them, but the records were of such a nature that statistical analysis was not possible.

TABLE I.

Written complaints to the New York City Water Department of fishes in the water supply, by months for eleven years.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1925......	..	..	..	..	..	..	..	..	..	..	2	..	2
1926......	..	..	..	..	..	..	..	..	13	4	2	..	19
1927......	..	..	..	..	..	..	..	1	..	1	..	..	2
1928......	..	..	..	..	2	..	..	..	..	..	..	..	2
1929......	..	..	..	..	..	..	..	..	..	1	..	..	1
1930......	..	..	..	..	..	..	..	..	..	..	1	..	1
1931......	..	..	..	..	..	..	..	..	1	..	..	2	3
1932......	..	..	..	..	..	..	..	..	..	..	..	..	0
1933......	..	..	..	1	..	..	..	..	..	2	..	..	3
1934......	..	..	..	..	..	..	..	..	40	61	8	6	115
1935......	..	..	..	..	..	..	..	..	..	49	..	..	49
TOTAL...	0	0	0	1	2	0	0	1	54	118	13	8	197
Mean.....	0	0	0	.09	.18	0	0	.09	4.91	10.72	1.18	.73	17.9

During the winter of 1935 a large number of samples was taken from the screens and these were measured and sexed. While this gives a fair idea of sizes in each group, it cannot be considered a measure of relative



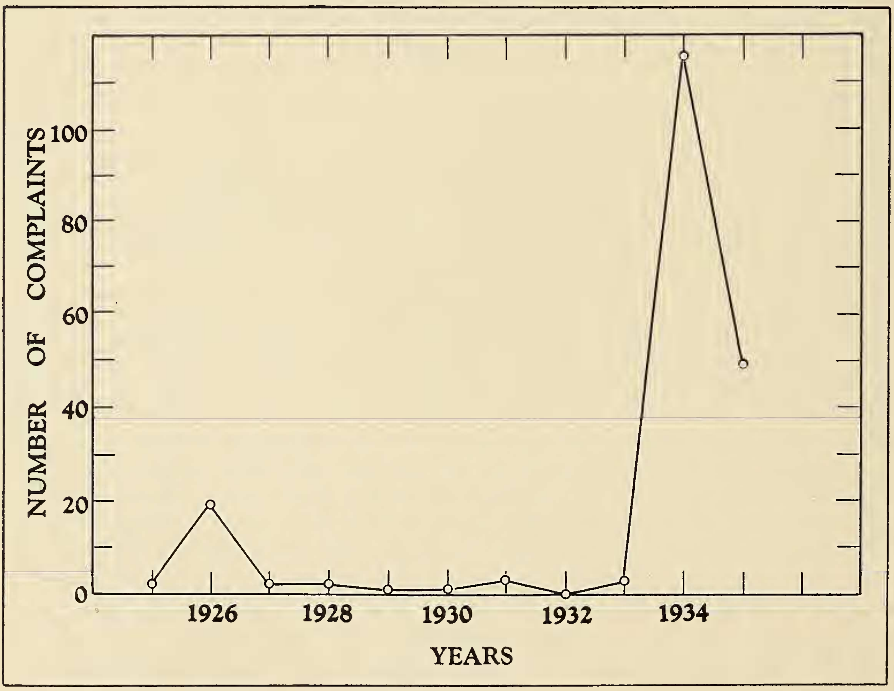
Text-figure 2.

Complaints of fishes emerging from taps made to the New York Department of Water Supply. Mean values by months for eleven years from 1925 to 1935 inclusive.

quantities of old and immature fish. Although the samples were random ones, these were already highly selected piles of fish as cleaned from the screen. This does not apply to the sex ratios of the adults, however, as the separation of males from females, in point of size, was so slight that a mechanical selection on this basis was out of the question. Bearing this out is the fact that distribution curves, not published, were found to be quite symmetrical and that the much smaller young were taken regularly. Table II gives these figures.

It will be noted that the sex ratios in the last column of Table II show a remarkable amount of variation. Apparently this is not accidental, since it follows a well-marked rise and fall as shown in Text-fig. 5. It would seem that the schools being caught on the screen varied in their sex composition in some regular manner. The various interpretations that may be placed on this phenomenon will be discussed subsequently, as will the nature of the 1936 sample.

During the late summer and fall large quantities of young fish are to be found at the upper end of Kensico Reservoir at a point where the flume from the Catskill watershed enters. A measured sample of these showed a mode at 4 cm., see Table II and Text-fig. 1. Scales of these specimens showed no winter ring but were entirely uniform in structure, as would be expected. The larger fish taken on the screens had been almost uniformly scaled by the tremendous washing they received, making adequate age analysis by this method impossible. However, such scales as could be found showed that the mean position of the first winter ring exceeded the August mode of 4 cm., and fell below the early spring mode of 5 cm., see Table III and Text-



Text-figure 3.

Complaints of fishes emerging from taps made to the New York Department of Water Supply. Total number of complaints per year for eleven years from 1925 to 1935 inclusive.

fig. 6. The interpretation of these data would seem to indicate the following:

The fishes, very much in evidence during the summer months, principally in the upper half of the lake, disappear from there as the water cools. At the same time some of the smaller ones, of the same year, emerge from household taps, while later the larger sizes catch on the coarse protective screens along with smaller sizes caught only because of the restricted openings induced by the larger fish. The peak of the movement of the year's fishes measured by observations of the workmen who are charged with the care of the screens, and the records of water consumer complaints, is during October and reaches chiefly from September to December. The larger and older individuals appear in their maximum numbers in February or March.

TABLE II.

Sizes and states of *Pomolobus pseudoharengus* taken from the screen at the outlet of Kensico Reservoir.

1935	Female				Male				Immature				Total	Sex Ratio
	No.	Max.	Mode[1]	Min.	No.	Max.	Mode	Min.	No.	Max.	Mode	Min.		
Feb. 15–16	109	12.3	11	9.5	18	13.5	10	9.5	115	7.0	5	3.5	242	6.4
Feb. 22....	70	12.7	10	9.5	4	10.5	10	9.0	100	6.8	5	3.7	174	17.5
March 1...	26	12.0	10	9.2	2	9.5	9	9.3	95	8.2	5	3.4	123	13.0
March 18..	7	12.0	11	10.5	5	11.0	10	9.0	2	5.5	5	5.0	14	1.4
April 8....	39	13.5	11	10.0	24	11.5	11	9.5	1	..	7	..	64	1.6
April 22...	41	12.2	10	9.4	4	12.0	10	10.0	20	6.4	5	5.0	65	10.2
May 6.....	29	11.7	10	9.5	6	11.4	9	9.0	99	6.5	5	3.7	134	4.8
May 20....	7	12.0	11	10.5	3	11.0	10	10.0	0	..	..	..	10	2.3
1936 Feb. 19....	12	14.0	12	10.0	9	13.2	9	9.0	3	5.0	5	4.5	24	8.9
Total......	340	..	..	..	75	..	..	..	435	..	..	..	850	..
Extremes..	..	14.0	..	9.2	..	13.5	..	9.0	..	8.2	..	3.4	..	..
Means.....	..	12.5	10+	9.6	..	11.5	10–	9.3	..	6.5	5+	4.1	..	4.5
1936	Fishes collected by seine in upper Kensico.													
Aug. 17....	..	..	..	..	..	..	..	..	300	6.0	4	2.6	300	..
Aug. 23....	..	..	..	..	..	..	..	..	64	6.3	4	3.6	64	..
Total fish examined........................													1214	

[1] The modes as used throughout this paper were picked from distribution curves of 1 cm. intervals. Extremes measured to the nearest mm. All measurements are in cm. and refer to standard lengths.

If these fishes are to be considered a recently landlocked form of the sea run *Pomolobus pseudoharengus*, it should seem that the fishes are merely acting according to their normal anadromous nature. There are, however, several reasons to question this close kinship between the two on the basis of observed habits. Spawning of the sea run *Pomolobus* occurs early in the spring in local waters. At Swimming River, New Jersey, for example, the spawning fish arrive from the last week in March to the middle of April. The old fish disappear about the middle of May. These fish have passed three or more winters. The males range from 22.2 to 27.3 cm. standard length and have a mode at about 24.2, while the females range from 24.2 to 27.3 cm. with a mode at about 26.0. This is based on a sample of 50 fish taken in 1923, in part discussed by Nichols and Breder (1926). In tributaries of the Hudson River at Troy, New York, Greeley (1935) observed spawning fish in the middle of May at a temperature of 52° F. This is considerably north of our locality and the slight difference in time is to be expected. The sizes of these fish are not given. Since the adult Kensico Lake fish do not appear on the screens until February there is certainly no downstream migration until much later and, supposedly, spawning is much later, on a considerably warmer temperature. Odell, at Seneca Lake, obtained his eggs from late May to mid-August. Of course this may be only the immediate influence of environment, but one would hardly expect such a difference in temperature thresholds. The whirling splash of the spawning fish described by Greeley is apparently identical to that of the landlocked form.

Text-figure 4.

A typical mass of *Pomolobus* removed from a screen at the Kensico outlet, March 2, 1935.

Concerning the wide differences in numbers coming from the lake (Table II and Text-fig. 3), there is one item that may be used to question this downstream migration. It has long been known that periodically there are heavy mortalities among these fishes in certain lakes and at such times windrows of dead fish may collect along the lake shores. Such a condition has never been noted in Kensico and it may be possible that due to its form, rate of flow, or other factors, fishes in a weakened and dying condition, which might otherwise strew the shore line, gravitate to the outlet screens. Since there was a period of eight years between outbreaks, it more or less suggests the population cycles common to so many organisms.

Another way to look at this would be to assume that only on an occasional year did a very successful spawning take place and that the heavy coating of the screens with fishes in 1934 represented the peak of the death rate of some earlier but peculiarly successful year class. Since our fish showed modes between 9 and 11 cm., it may be that most of them had passed through four to six winters, which would place the successful hatch between 1929 and 1931, as suggested by Table III. Supporting this are the data from the screens in 1936. The mode and range of the females exceed anything in 1935, whereas the young and males are typical of the preceding year. If these females represent the residue from the previous year of that abnormally successful year class, such figures would be expected. Since the males of such fishes frequently mature a year earlier than the females, it would not be surprising to find few left. It may be noted that these 1936 males cover the full spread of variation found in the entire 1935 collection. The relatively few fishes in the 1936 collection can scarcely be considered as invalidating these views, since the 1935 material is remarkably uniform and the mode of the 1936 collection closely approximates the extreme size of females for the previous year—a type of selection almost impossible to make artificially, especially in view of the constant size of the males.

TABLE III.

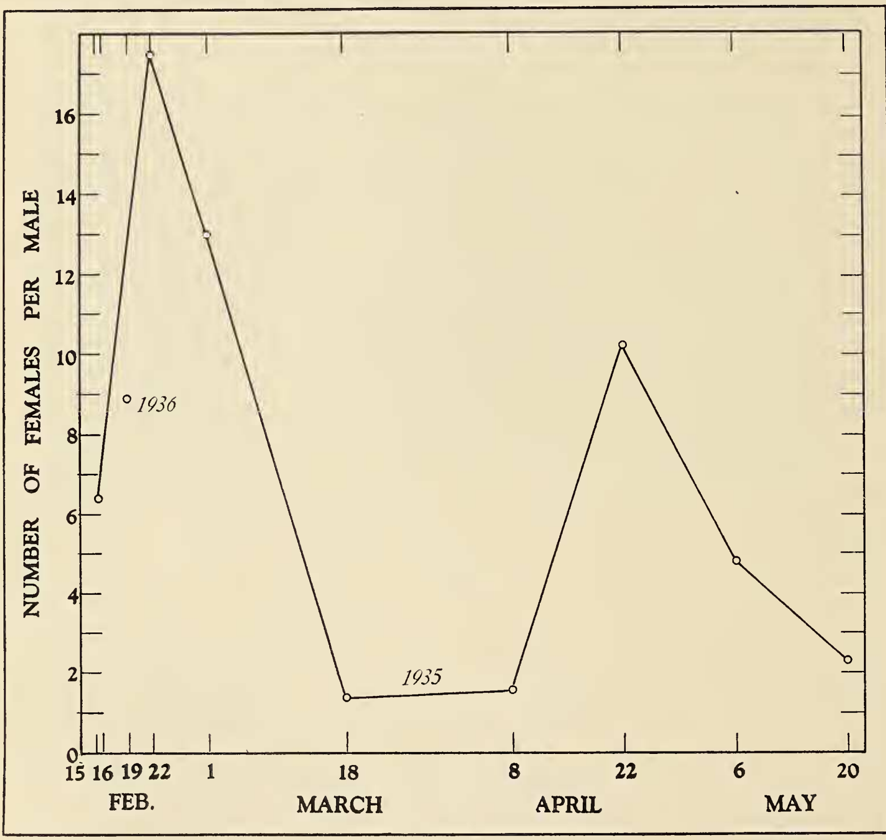
Comparison of Seneca Lake *Pomolobus* with growth from indications of scale marks on Kensico Lake specimens.

Annulus	SENECA LAKE[1]		KENSICO LAKE	
	Female	Male	Female[2]	Male[3]
1	5.5	5.5	4.3	4.7
2	12.1	11.4	6.7	7.4
3	12.5	12.1	7.8	8.2
4	13.4	13.9	9.1	9.2
5	13.9	14.0	10.8	10.5[4]
6	....	....	11.1	....
7	....	....	12.0[4]	....

1 Data from Odell (1934); mean values of his Table I.
2 Mean of 5 females.
3 Mean of 3 males.
4 Scale edge in early spring = actual standard length. All measurements in cm. standard lengths.

As noted in another connection, scale examination from these screen-caught fish was not satisfactory, but all examined appeared to be in their fourth year or over. Adventitious and, perhaps, spawning rings were found so confusing that on the basis of our scant material it would be unwise to attempt a close analysis of these data. There are, however, two pertinent points that emerge. One is that there seemed to be no appearance of second or third year fish on either a basis of modes or scale examinations. In the latter the mean value for the second winter was 6.7 cm. female and 7.3 cm. male. Compared with Table II it is clear that this is close to the extreme maximum of size for immature fish and just where there were exceedingly few individuals taken—the upper end of the distribution curve; likewise the third ring with mean values at 7.8 cm. female and 8.2 cm. male. It is not until the fourth annulus is reached with mean values at 9.1 cm. female and 9.3 cm. male that the minimum values of the mature fish of Table II are reached. Although these scale data are fragmentary, it is clear from the measurements of the fish that some classes, which lie between the young of the year and the smallest adults obtained, are practically or completely absent. If all classes had been present on the screens, with the annuli falling where they do, no such clear separation, as indicated by Table II, could be possible. Furthermore, immature, male and female groups showed sharp peaks to their very symmetrical distribution curves. The immature fish from the screens (Table II) show a single annulus near the edge of the scale, as of course they should.

The other evident item is the relatively slower growth of our fish as compared with Odell's. No matter what age be ascribed to our fishes, making allowance for the misinterpretation of adventitious or spawning marks, none reached the sizes he obtained. Our tentative values as compared with his are given in Table III and in Text-fig. 6. These fish do not reach the modal sizes his did when laying down their third winter ring. The Kensico fish, on this basis, have an extremely rapid growth before the first winter and then slow down gradually. Odell's material, on the other hand, shows materially faster growth, including the second season. Lest it be thought that we merely missed the first annulus, it may be pointed out that the scales from the fish collected by net in August were carefully examined and showed no ring, whereas those slightly larger, taken in the screens in spring, showed one most clearly. This agreed in position with the first ring on the scales of the larger fish. It is possible that this difference in growth rate between Seneca and Kensico fishes may be associated with a temperature



Text-figure 5.

Sex ratio by dates of samples of *Pomolobus pseudoharengus* caught on the screens at Kensico Reservoir during 1935 and one for 1936. The figures in the vertical index represent the number of females divided by the number of males present.

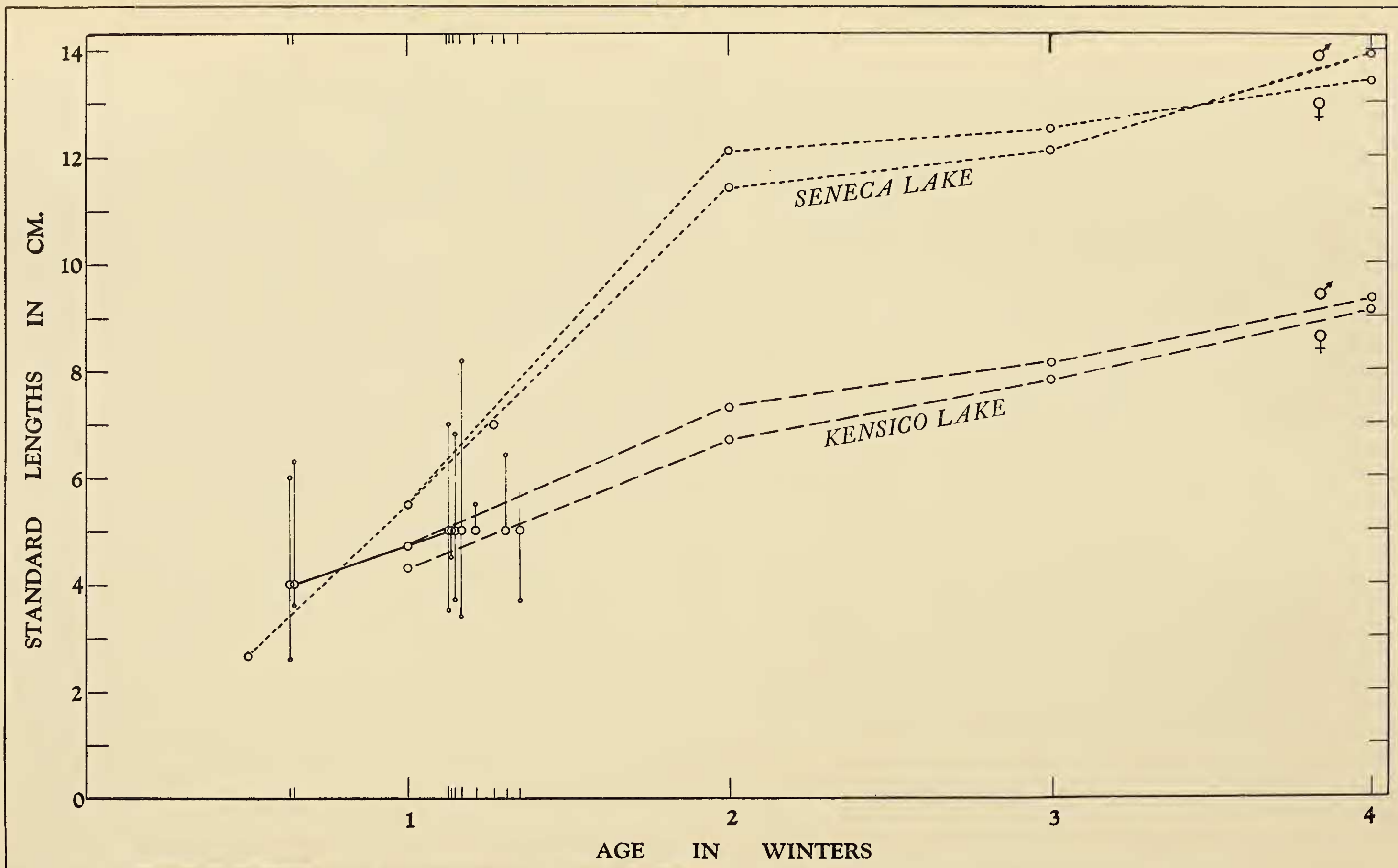
differential, but on this point we have no comparative data. The water delivered to Kensico Reservoir is treated with alum and soda ash before it reaches there and sometimes copper sulphate is used in the lake. The alum is precipitated in the upper part of Kensico. See Hale and Dowd (1917) for a discussion of the chemical and physical conditions in this lake, including a discussion of the thermocline which they found forming at between 16 to 23 feet. Later data indicate that it is apt to form at between 20 and 30 feet. This chemical treatment should have a depressing effect on the plankton and it may be that at times when the species is numerous a starvation dwarfing ensues. It is pointed out in this connection that the fishes taken on the screens were entirely empty of identifiable remains. However, there may be a complete cessation of feeding at this time of year. The fish of the year taken by other means were found to contain microcrustacea only. Although no effort was made to study this feature in detail, it agrees well with the data of Odell, for in August, the month of capture of these fish, he reported the stomach contents as 90% microcrustacea. He does not give the size of his fishes, but in a personal communication he stated that there was no feeding differential to be noted with different size groups.

Regarding the physical conditions, it may be mentioned that temperatures in Kensico ranged in 1935 from a mean of 63° in August to 34° in February. Thus the young fish began to appear in the faucets just after the summer peak of temperature was passed (Text-fig. 2) and the adults reached their maximum congestion on the screens about coincident with the lowest winter temperature. According to the Water Department records, the pH has been slowly dropping since 1930 when the average was 6.9, whereas in 1935 it had reached 6.7, which figure it had shown since 1933. We are unprepared to draw any inferences from these data, if indeed they have any important bearing on the fish under consideration.

The variation in sex ratio expressed in Table II and Text-fig. 5 is difficult of interpretation, but probably has to do with a differential movement of the sexes in regard to their spawning beds. The females markedly exceed the males in number in late February and again in late April. If this species possesses a 1 to 1 sex ratio it would seem that the males are more generally successful in avoiding disaster on the screens, which in turn would indicate less of a tendency to drop downstream. Just why this should be most marked in February and again in April is not at all clear at this time, unless the females descend to the screens at a faster rate after they are once started, and remain longer after the males move upstream. Because of the virtual failure of the fish to appear on the screens in 1936, a continuance of this study was impossible. We question the validity of the apparently more rapid growth of the males, as based on scale examination, preferring at this time to consider it as probably due to the small number of fish involved. Likewise, corrections for Lea's phenomenon, as given by Odell, would be pointless in connection with our material, because of the relative coarseness inherent in these figures based on so few fishes.

Young fish of the year showed a modal length of 4 cm. in the latter part of August, which reached 5 cm. before the cold weather checked increment, as indicated in Table II. If it is true that a successful spawning occurs relatively rarely, it may be that intermediate classes drop out and all those of the immature class measured by us were doomed to an early demise. At least it is difficult to conceive how otherwise to account for the condition and sizes of fish caught on the screen in 1936.

The items here discussed necessarily lead one to infer that these violent epidemics of *Pomolobus* in Kensico Lake belong with that great group of periodical fluctuations of animal populations and that, other conditions remaining static, a return of large numbers should not be expected for some little time, perhaps for a period somewhat approximating that of the last



Text-figure 6.

Growth of *Pomolobus pseudoharengus.* The clear circles through which verticle lines pass to smaller circles represent, respectively, modes and extremes of all immature fish measured. Those before the first winter were taken by seine at the upper end of Kensico Lake in August and showed no annuli. Those past the first winter were taken from the outlet screens from February to May and showed one annulus. The dashed line shows calculated lengths of larger fish for the first four winters taken from the screens during the same period. The dotted line is from table 1 of Odell (1934) from Seneca Lake. The latter fishes have a clearly faster growth rate than the Kensico Lake fish. Modes of all mature Kenisco fish are 10+ cm. for females and 10— cm. for males, (not shown in this figure). The maximum was a female of 14.0 cm. and the minimum a male of 9.0 cm.

interval. This species is preyed upon to a large extent by *Cristivomer*, as indicated by Eaton (1928) and Odell (1934). The latter is present in Kensico in small numbers. Forster (1935) has considered the lake trout, as well as other species, as factors in the control of this herring in Kensico Reservoir, a not unimportant item in the maintenance of a satisfactory water supply of a great city. The probable value of such control measures can hardly be estimated at this time.

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